

## DEVELOPMENT OF A TECHNOLOGY FOR PRODUCING QUENCHED CULLET FOR FOAM GLASS MANUFACTURE

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A scheme for producing quenched cullet to be used in subsequent processing and in foam-glass manufacture is presented. The problems of increasing the energy efficiency of the technological processes and lowering the cost of diatomite-based batch are examined.

**Key words:** cullet, silica-containing raw material, diatomite, batch, quenched glass, foam glass.

Foam glass possesses a unique mix of physical-chemical properties and its technical characteristics make it the most effective and promising heat-insulating material. However, its use and manufacture in Russia and the Republics of the former Soviet Union remain extremely limited. Increases in production and new manufacturing capacities are held back not by the lack of modern technologies and the appropriate equipment but by the fact that the specific cost of foam glass remains high compared with other composite materials used in the construction industry. In addition, a number of problems arise in organizing profitable production of foam glass largely because of a lack of inexpensive, high-quality cullet. The origin of the latter circumstance is that glass enterprises make substantial use of their own glass wastes. Moreover, there is no developed system for centralized collection of cullet, and in most regions there are no cullet reprocessing and salvaging enterprises.

The chemical uniformity of cullet from secondary raw-materials bases is also of no small importance for manufacturing foam-glass plates, blocks and grit as well as granular foam glass. Though a relatively inexpensive raw material (neglecting the costs of collection, sorting, washing, drying and comminution as well as magnetic and optical separation and classification) such mixed cullet wastes make it difficult to guarantee uniformity of the chemical composition and consistent quality of foam glass, especially glass produced on high-capacity mechanized and automated lines [1].

For this reason, to increase the quality of foam glass in large-volume production it is desirable to use as raw material glass which is specially synthesized in tank furnaces from batch specially prepared using inexpensive and readily avail-

able components such as crushed granite stone screenings [2], marshallite, opoka, zeolite and other naturally occurring opal-cristobalite materials [3]. Among such components diatomite, which is a loose or weakly cemented sedimentary rock formed during the Jurassic period by marine and lacustrine deposits of the shells of ancient fossil algae (diatoms) with nanoporous structure consisting of more than 80% amorphous silica, suitable for complete or partial replacement of quartz sand, a material which is scarce, in the production of glass frit, foam glass and other types of glass [4].

A technological scheme of a production plant using diatomite raw material for the manufacture of quenched cullet, which is an intermediate product in the production of high-quality foam-glass by powder technology, has been developed at Stromizmeritel' JSC for the DIAMIX Group. This group of companies includes a scientific-technical center, a diatomite combine and the largest diatomite deposit in Europe — the Inzenskoe deposit in Ul'yansovsk Oblast'. In this scheme the construction and start-up of a plant producing 100 tons quenched cullet per day must be accomplished in a single phase on vacant sites at the diatomite combine, which is located in direct proximity to the quarry where diatomite is produced. According to the architectural-construction and technological design concepts, the main production subdivisions and sections of the plant lie on a small territory with dimensions 52 × 102 m (Fig. 1) and include the following: receiving division 1; diatomite conveyor gallery 2; diatomite processing section 3; batching-mixing line 4; quenched-cullet production shop 5; smokestack 6; conveyor gallery 7; and, silo storage 8 of the finished product.

In this technology diatomite with 37 – 50% moisture from a quarry located no more than 1 km from the diatomite combine is trucked to the receiving division of the plant, where it is poured into a hopper 1 (Fig. 2) equipped with a

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The compaction operation not only increases the bulk weight of the light-weight batch prepared on the basis of diatomite but it also increases its chemical activity and decreases dust generation and loss of light-weight fractions at the time the batch is loaded into the glassmaking furnace.

The molten glass is poured in a continuous stream along the extraction channel 2 from the glassmaking furnace 1 (Fig. 4) into the water-cooled feed spout 3 whence it enters the granulator 4, which comprises a two-level drag conveyer placed in a tank with water (drum granulators can also be used). The molten glass is intensively cooled from the sharp temperature difference arising from the contact with water and breaks up into fine granules no larger than 5–8 mm. The moistened quenched glass with residues of droplet moisture is transferred from the granulator onto the belt conveyer 5 and raised by the elevator 6 to a higher level in order to load the material into a three-step heat-exchange apparatus 7 with inclined louvered lattices (developed at the First President of Russia B. N. El'tsin Urals Federal Institute). This facility operates as follows. Upward flowing exhaust gases taken from the glassmaking furnace (the temperature of the drying agent at the entrance into the apparatus is about 300°C) are intensively blown through a thin layer of material moving downward under gravity along the louvered lattices. The three-step counterflow motion of the moist quenched glass and hot exhaust gases promotes effective convective heat transfer and greatly lowers (compared with drying in the drying drum) the specific consumption of the coolant.

The depleted drying agent with temperature 115°C enters the cyclones 8, where fine dust is removed from in the agent, after which an exhauster 9 discharges it through the smoke-stack into the atmosphere. The dried material flows from the bottom cut-off of the last lattice through the unloading window onto a gallery belt conveyor 10 whence an elevator 11, tubular switch 12 and conveyor 13 distribute it over the finished product storage silos 14, 15 and 16. The quenched glass is unloaded from the silos, whose total volume is 450 m<sup>3</sup>, into trucks and checked with strain-gauge floor scales 17.

It should be noted that the capacity of the quenched-glass production plant 100 tons/day was chosen on the basis of the anticipated delivery of this product to neighboring regions, where the time is ripe for building enterprises for the production of different products made of foam glass. This volume of quenched glass makes it possible to produce about 180,000 m<sup>3</sup> of foam glass articles per year, which is, of course, a large amount for a single region. The production of 40,000–60,000 m<sup>3</sup> foam glass per year for one region is optimal; this level corresponds to glass furnace capacity 20–30 tons molten glass per day. Once-through furnaces are most efficient for this level of production. Such furnaces are planned for cullet production [5].

Nonetheless, since there is an acute need for cullet in the glass industry and the shortage of high-quality cullet for the production of high-quality foam glass with stable physical-

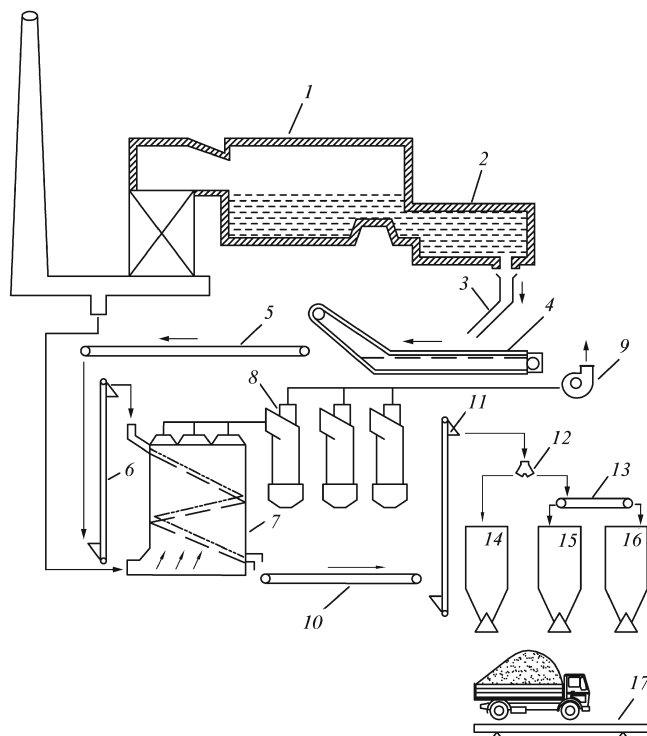


Fig. 4. Transport flow scheme of the quenched-glass production shop.

chemical characteristics, the development of this scheme, which government experts are now analyzing, and the subsequent construction of a quenched-glass production plant are timely and very urgent.

Together with the development of the design scheme documentation for the quenched glass production plant, Stromizmeritel' JSC specialists have synthesized several batch mixes based on diatomite (two batch mixes, a method for preparing batch and the process line have been patented), conducted trial laboratory smelting of glass and performed studies of the physical-chemical properties of the foam-glass samples obtained. The main thrust of the studies was to expand the raw-materials base of the silicon-containing raw material and decrease energy consumption on the fabrication of quenched glass for foam-glass production. Thus, in the course of comparative experiments on mixing, compacting and melting batch prepared using different kinds of silica-containing raw material (the presence of two suspension hoppers for these materials in the feeding-mixing line makes it possible to vary the composition) it was found that the bulk density of batch containing quartz sand as the silica-containing component is 1.3–1.4 tons/m<sup>3</sup>, making possible to feed this batch efficiently into a glassmaking furnace using the most widely used batch feeders. But this batch with 4.5–4.7% moisture content undergoes virtually no compaction, and if expensive binding materials are not used, it cannot be granulated.

Batch in which quartz sand is completely replaced with diatomite compacts better and melts at lower temperatures, but its bulk density is comparatively low  $0.5 - 0.6 \text{ tons/m}^3$ , which makes it difficult to feed such batch into a glass-making furnace, leads to active loss of light-weight fractions during glass making and makes it necessary to increase the volumes of the mixers and bunkers for batch storage at a prescribed production level. In addition, such batch is prone to frequent bridging and arching in intermediate storage. For this reason the authors have proposed and investigated the following batch composition for making quenched glass (content by weight): 19 – 23% calcinated soda, 13 – 16% dolomite, 0.45 – 1.0% sodium sulfate, 30 – 35% quartz sand with 0.5% moisture content and 0.1 – 0.63 mm fractions and 28 – 33% diatomite with 15 – 30% moisture content and fractions smaller than 0.1 mm.

An advantage of this batch composition is that the partial replacement of quartz sand with diatomite with a water-saturated nonporous structure makes it possible to eliminate the batching wetting process in the mixer, greatly accelerate heat transfer inside diatomite particles and lower the glassmaking temperature. At the same time the melting temperature decreases as a result of the extended inner surface of the porous dolomite particles as well as the active hydration of silica. Because moisture is present inside the diatomite particles during glassmaking sols and gels of silicic acids are formed during the activation of silica hydration reactions at temperatures as low as  $50^\circ\text{C}$ . Partial silicate formation starts at  $200^\circ\text{C}$ , and a eutectic and a liquid phase of melted eutectics as well as complex silicates start appear at  $750^\circ\text{C}$ . Glass formation is completed at  $1250 - 1350^\circ\text{C}$ , which is  $100 - 150^\circ\text{C}$  lower than the analogous temperatures of thermal processes occurring in batch prepared using quartz sand.

An additional improvement of the energy efficiency of quenched glass production from such batch is gained because in such a diatomite-based batch-preparation technology there is no need to dry diatomite in a drying drum. This is because even at 30% moisture content almost all moisture

is concentrated inside diatoms because of the high adsorption properties of diatomite and the material retains good flowability with a stable angle of repose. However, by combining in silica-containing raw material quartz sand and diatomite, whose bulk densities and particle-sizes are different, the bulk density of the compacted batch can be increased to  $1.0 - 1.1 \text{ tons/m}^3$ , which considerably improves the batch storage and transport processes. In addition, for different particle-sizes of the silica-containing raw material the pressure required for compaction is lower and the corresponding equipment consumes less energy.

In summary, the development of a technology for producing batch using diatomite makes it possible to obtain initial raw material for manufacturing foam glass with stable physical-chemical characteristics, lower the cost of producing the finished product and increase the energy efficiency of foam-glass production technology.

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